A Generic Framework for the Economic Valuation of Insurance Liabilities

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1 Introduction

This paper derives a generic framework for determining the market value of insurance liabilities comprising of three components: the risk-free discounted value of the best estimate liability cashflows, a risk margin, and a deferred tax liability. Important features of this framework are that it allows for a wide range of capital allocation methods, and that it is consistent with the standard accounting definition of deferred tax as well as with the insurer's overall cost-of-capital. Having a generic framework supports the efficient implementation of a range of alternative valuation methods in a multi-valuation environment, such as the Baseline Delta Approach being developed at Swiss Re[2]. Not only does this significantly reduce systems costs, it also lowers funding costs to the extent that it improves transparency and comparability across the insurance industry.

The proposed framework is founded on the dividend discount model. This principle is used to illustrate the simplifying assumptions underlying the standard Solvency II valuation approach, which includes a best estimate liability and risk margin based on the cost-of-capital approach. It is also shown that the capital cost risk margin can be interpreted as the risk-free discounted value of the capital cashflows, which are comprised of the initial capital requirement and the subsequent release of capital requirements over time. This means that the market value of insurance liabilities combined with the initial capital requirements should be sufficient to replicate all cashflows associated with the liabilities, including the capital cashflows.

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[2] See article by Gerhard Lohmann and Markus Seifert titled "An innovative approach to Multi-GAAP accounting for the (Re-)Insurance industry and how this will benefit the CFO", https://www.linkedin.com/pulse/innovative-approach-multi-gaap-accounting-industry-how-lohmann.

The standard cost-of-capital approach is then generalised by allowing for debt to partly fund the capital requirements and by allowing for tax and liability funding costs. Liability funding costs include the costs of replicating the financial market risk embedded in the liability cashflows, illiquidity premiums, as well as own-credit risk, or credit risk in the case of insurance assets. Tax requires special consideration because the standard accounting deferred tax calculation method is shown to be incompatible with the standard risk margin calibrated on a pre-tax basis. To ensure consistency, a separate component needs to be added to the risk margin for capital costs. In addition, it is shown how to calibrate the cost-of-capital rate for insurance activities, a key parameter in the risk margin, to ensure consistency with the firm's overall cost-of-capital by allowing for investment risk, excess capital, and new business.

The framework is shown to be consistent with Solvency II, the Swiss Solvency Test, Market Consistent Embedded Values, and the new international financial reporting standard IFRS 17. As a result, it provides the basis for interpreting the cost-of-capital parameters used in these alternative valuation standards. In particular, it is highlighted that they typically do not properly allow for tax.

Components of the market value of insurance liabilities:

❶ **Best estimate liability**, representing the present value of best estimate liability cashflows (claims and expenses, less premiums) discounted at risk-free rates.

❷ **Deferred tax liability**, representing tax on temporary differences between the value of the insurance liabilities for tax purposes and their market value.

❸ **Risk margin**, comprised of two parts:

- **capital margin** reflecting the pre-tax cost of funding the capital requirements of the in-force insurance business, which may be met by a combination of equity and debt,
- **liability margin** reflecting the pre-tax allowance for financial market risk in the liability cashflows as well as the cost to the client of providing funding via the purchase of the insurance contract, including own credit risk, or credit risk in the case the underlying contract is an economic asset, and liquidity costs depending on the liquidity characteristics of the liability cashflows.

2 Conceptual background

This chapter highlights the simplifying assumptions underlying the standard cost-of-capital approach, which is used to specify the Solvency II risk margin. These simplifying assumptions are then relaxed in chapters 3 and 4 to develop a more generic framework for valuing insurance liabilities. This chapter also shows that the risk margin can be interpreted as the risk-free discounted value of the cashflows needed to fund the capital requirements.

Throughout this paper the term $d_{t,k}^{x}$ is used to denote a factor for discounting cashflows from time k to time t based on risk-free interest rates plus a spread denoted x. No spread is shown in the case of risk-free discount factors. The corresponding forward interest rate is denoted $r_{t,k}^{x}$ (see the appendix for more details on notation).

2.1 Deriving the cost-of-capital approach

To illustrate the core principles underlying the generic framework for valuing insurance liabilities, we start with a simplified case of an insurance company that:

i. is entirely equity funded and holds no debt,

ii. has capital requirements specified as an amount in excess of the market value of insurance liabilities,

iii. is not subject to tax,

iv. has liability cashflows that are not subject to financial market risk and are default-free (or fully collateralised),

v. takes no investment risk and does not engage in any other non-insurance activities,

vi. has no excess capital or pays out all excess capital in the form of dividends,

vii. does not plan to write new business and the market places no value on future new business.

As the insurer is assumed to have no excess capital, dividends are equal to economic earnings plus change in capital requirements, denoted $DIV_t = EE_t + MVIE_{t-1} - MVIE_t$. In addition, applying the dividend discount model, the economic value of the equity at time t equals the present value of future dividend payments discounted at the insurer's cost-of-equity rate, represented as a spread of ε over risk-free rates. Hence:

$$MVIE_t = \sum_{k=t+1}^{\infty} DIV_k \cdot d_{t,k}^{\varepsilon}$$

This formula can be rearranged to show that:

$$MVIE_{t-1} \cdot \left(1 + r^{\varepsilon}_{t-1,t}\right) - MVIE_t = DIV_t$$

Using the above definition of dividend payments, this can be simplified to show that projected capital costs equal projected economic earnings. Economic earnings are comprised of the liability cashflows, change in market value of the insurance liabilities, and investment income on total assets (backing both the liabilities and capital requirements). As a result:

$$MVIE_{t-1} \cdot r^{\varepsilon}_{t-1,t} = EE_t = CF^l_t + MVIL_{t-1} - MVIL_t + MVIA_{t-1} \cdot r_{t-1,t}$$

Rearranging this equation to solve for the market value of the insurance liabilities produces:

$$MVIL_{t-1} \cdot \left(1 + r_{t-1,t}\right) - MVIL_t = -CF^l_t + MVIE_{t-1} \cdot \left(r^{\varepsilon}_{t-1,t} - r_{t-1,t}\right)$$

Solving this equation recursively, the market value of insurance liabilities is then given by:

$$MVIL_t = BEL_t + RM^c_t$$

where:

i. $BEL_t = \sum_{k=t+1}^{\infty} -CF^l_k \cdot d_{t,k}$ is minus the best-estimate value of the liability cashflows at time *t*.

ii. $RM^c_t = \sum_{k=t+1}^{\infty} MVIE_{k-1} \cdot \left(r^c_{k-1,k} - r_{k-1,k}\right) \cdot d_{t,k}$ is a capital cost risk margin at time *t*, where $r^c_{t-1,t} = r^{\varepsilon}_{t-1,t}$.

This is consistent with the cost-of-capital approach used in Solvency II and illustrates the specific circumstances in which the cost-of-capital spread used in the risk margin is equal to the insurer's equity cost-of-capital spread.

2.2 Alternative specification of the risk margin

The previous section shows how the risk margin used in the cost-of-capital approach is derived and how it relates to the equity cost-of-capital, based on simplified assumptions. This section provides an alternative interpretation of the risk margin, which allows the above approach to be generalised to take account of alternative potential specifications of capital requirements associated with insurance activities.

As shown in the previous section, the standard specification of the capital cost risk margin is given by $RM^c_t = \sum_{k=t+1}^{\infty} MVIE_{k-1} \cdot \left(r^{\varepsilon}_{k-1,k} - r_{k-1,k}\right) \cdot d_{t,k}$. In addition, dividend payments are equal to the change in the capital requirements plus the economic return on capital at the cost-of-capital rate, given by $DIV_t = MVIE_{t-1} \cdot \left(1 + r_{t-1,t}^{\varepsilon}\right) - MVIE_t$. As a result, the risk margin can be reformulated and then simplified as follows:

$$RM_t^c = \sum_{k=t+1}^{\infty} \left(DIV_k - MVIE_{k-1} \cdot \left(1 + r_{k-1,k}\right) + MVIE_k\right) \cdot d_{t,k} = \sum_{k=t+1}^{\infty} DIV_k \cdot d_{t,k} - MVIE_t$$

In other words, the risk margin can be interpreted as the risk-free discounted value of the release of capital requirements less the initial capital contribution or the cost of replicating the capital cashflows using risk-free instruments. As shown in the following chapter, this alternative formulation is useful when the capital requirement is derived from a non-economic regulatory standard.

3 Deriving a generic economic valuation framework

This chapter develops a generic framework for valuing insurance liabilities by extending the simplified base case established in chapter 2, firstly by allowing for debt funding and residual capital requirements, and then by adding tax. The framework is completed by allowing for financial market risk associated with the liabilities, as well as illiquidity premiums and credit risk, where credit risk reflects own credit risk in the case of insurance liabilities and counterparty credit risk in the case of insurance assets. As the allowance for financial market, credit risk, and illiquidity premiums essentially reflects the cost to the insurer of securing funding from the policyholder, they are termed liability funding costs.

3.1 Allowing for debt funding

Building on the simplified example from section 2.1, assume that total capital requirements are funded by a mix of equity and subordinate or hybrid debt, denoted $MVIC_t = MVIE_t + MVIH_t$, and that the interest expense on hybrid debt is based on a forward rate denoted $r_{t-1,t}^{\gamma}$. Note that it is implicitly assumed that debt can be redeemed at any time at zero cost, or redeployed to support new business. In this case economic earnings are given by:

$$EE_t = CF_t^l + MVIL_{t-1} - MVIL_t + MVIA_{t-1} \cdot r_{t-1,t} - MVIH_{t-1} \cdot r_{t-1,t}^{\gamma}$$

where the assets backing the insurance activities are the sum of the market value of the insurance liabilities and the capital requirements, given by $MVIA_t = MVIL_t + MVIE_t + MVIH_t$.

Equating this formula for economic earnings with the equity cost-of-capital, $MVIE_{t-1} \cdot r^{\varepsilon}_{t-1,t} = EE_t$, and recursively solving for the market value of the liabilities, as in section 2.1, results in:

$$MVIL_t = BEL_t + RM^c_t$$

where:

i. $BEL_t = \sum_{k=t+1}^{\infty} -CF^l_k \cdot d_{t,k}$ is minus the best-estimate value of the liability cashflows at time *t*.

ii. $RM^c_t = \sum_{k=t+1}^{\infty} MVIC_{k-1} \cdot \left(r^{rc}_{k-1,k} - r_{k-1,k}\right) \cdot d_{t,k}$, where the cost-of-capital rate is the weighted average of the equity and hybrid rates.

This shows that the cost-of-capital rate is equal to the weighted average cost-of-capital, depending on the extent to which the capital requirements are funded by equity capital or hybrid debt. The approach used in this section can be extended by also allowing for senior debt financing. Assuming that total capital is given by $MVIC_t = MVIE_t + MVIH_t + MVID_t$ and the interest expense on senior debt is based on a forward rate denoted $r^{\delta}_{t-1,t}$, then the weighted average cost-of-capital is given by:

$$r^{rc}_{t-1,t} = \left(MVIE_{t-1} \cdot r^{c}_{t-1,t} + MVIH_{t-1} \cdot r^{\gamma}_{t-1,t} + MVID_{t-1} \cdot r^{\delta}_{t-1,t}\right) / MVIC_{t-1}$$

3.2 Allowing for residual capital requirements and excess funding

The above approach assumes that capital requirements consist entirely of a defined amount of risk capital and that debt is allocated in the same proportion to all contracts. However in practice, there will often be additional regulatory capital requirements specified with reference to a non-economic balance sheet. In this section, we generalise the capital cost risk margin by decomposing the total capital requirement into a risk capital component and any additional residual capital held to meet non-economic regulatory capital requirements.

In the case that total capital requirements are derived by deducting the market value of insurance liabilities from the market value of assets needed to cover the statutory value of the insurance liabilities and statutory capital requirements, the standard risk margin calculation is intractable. This is because, in this case, the risk margin is based on the market value of insurance liabilities, and the market value of insurance liabilities in turn includes the risk margin. To obtain a tractable solution, projected dividend payments can alternatively be derived from the market value of insurance assets, which are equal to the market value of total assets less any excess statutory capital and any excess hybrid or senior debt not backing insurance activities, as follows:

$$DIV_t = CF^l_t + MVIA_{t-1} \cdot \left(1 + r_{t-1,t}\right) - MVIA_t = \left(MVIA_{t-1} - BEL_{t-1}\right) \cdot \left(1 + r_{t-1,t}\right) - \left(MVIA_t - BEL_t\right)$$

The risk margin can then be calculated using the alternative formula (see section 2.2), namely:

$$RM_t^c = \sum_{k=t+1}^{\infty} DIV_k \cdot d_{t,k} - MVIE_t = \sum_{k=t+1}^{\infty} DIV_k \cdot \left(d_{t,k} - d_{t,k}^c\right)$$

This assumes that both the risk and residual capital components are backed by the same mix of equity, hybrid debt, and senior debt. However, in practice the risk capital component should be backed by loss-absorbing capital only, namely equity and qualifying hybrid debt, whereas the residual component could potentially be funded at lower cost using collateral facilities or senior debt issued at Group level. To allow for this, the risk margin can be split into a standard risk margin for risk capital and alternative risk margin, based on the discounted value of capital cashflows, for residual capital, given by $RM_t^c = RM_t^{rc} + RM_t^{zc}$ where:

$$RM_t^{rc} = \sum_{k=t+1}^{\infty} MVRC_{k-1} \cdot \left(r_{k-1,k}^{rc} - r_{k-1,k}\right) \cdot d_{t,k}$$

$$RM_t^{zc} = \sum_{k=t+1}^{\infty} CF_k^{zc} \cdot \left(d_{t,k} - d_{t,k}^{zc}\right)$$

where:

i. $CF_t^{zc} = BE_{t-1}^{zc} \cdot \left(1 + r_{t-1,t}\right) - BE_t^{zc}$ is the residual funding cash-flow at time *t*.

ii. $BE_t^{zc} = MVZC_t + RM_t^{zc} = MVIA_t - BEL_t - RM_t^{rc} - MVRC_t$ is the residual funding requirement at time *t*, including residual funding costs.

iii. $r_{t-1,t}^{rc}$ and $r_{t-1,t}^{zc}$ are weighted average cost-of-capital rates for the risk and residual capital components, respectively.

Note that this requires that an insurer's equity capital, hybrid debt, and senior debt is allocated individually to back risk capital, residual capital, and non-insurance activities (referred to as excess equity capital, excess hybrid debt, and excess senior debt in section 4.1).

3.3 Allowing for tax

Tax gives rise to additional cash payments and also needs to be taken into account in determining the capital cost rate used to compute the risk margin. As a result, tax is an integral part of the liability valuation and the allowance for tax in the calibration of the risk margin depends on the method used to calculate deferred tax.

We assume that the insurer is subject to corporate tax on profits at a rate τ for all future years and that taxable profits are based on a tax balance sheet, which values insurance liabilities and assets on a different basis. As a result, tax is payable on the sum of the best estimate cash-flow, change in the tax value of the insurance liabilities, and taxable investment returns. Building on the simplified example from section 3.1 and allowing for hybrid debt only, after-tax economic earnings are given by:

$$EE_t = CF_t^l + MVIL_{t-1} - MVIL_t + MVIA_{t-1} \cdot r_{t-1,t} - \tau \cdot \left(CF_t^l + TVL_{t-1} - TVL_t + TVIA_{t-1} \cdot r_{t-1,t}^{\text{tax}}\right)$$
$$-(1-\tau) \cdot MVIH_{t-1} \cdot r_{t-1,t}^{\gamma} + DTIA_{t-1} - DTIA_t$$

where:

i. $TVIA_{t-1} \cdot r_{t-1,t}^{\text{tax}}$ is the taxable income on the assets backing the insurance liabilities and capital.

ii. $DTIA_t = \tau \cdot (MVIA_t - TVIA_t)$ is the deferred tax liability on the assets, and the unwind of this liability is given by $DTIA_{t-1} - DTIA_t = \tau \cdot \left(TVIA_{t-1} \cdot r_{t-1,t}^{\text{tax}} - MVIA_{t-1} \cdot r_{t-1,t}\right)$.

iii. $MVIA_t = MVIL_t + DTIA_t + MVIH_t + MVIE_t$ is the market value of the assets backing insurance activities.

Equating the after-tax economic earnings to the equity cost-of-capital, $MVIE_{t-1} \cdot r_{t-1,t}^{\varepsilon} = EE_t$, and recursively solving for the market value of the liabilities, as in section 2.1, results in:

$$MVIL_t = BEL_t + RM_t^c + \sum_{k=t+1}^{\infty} \tau \cdot \left(CF_k^l + TVL_{k-1} - TVL_k + TVIA_{k-1} \cdot r_{k-1,k}\right) \cdot d_{t,k}$$

The third term in this equation is the present value of future tax payments. To simplify this term, the assets backing insurance activities can be split into $TVIA_{k-1} = TVL_{k-1} + (TVIA_{k-1} - TVL_{k-1})$. In addition, note that:

$$\sum_{k=t+1}^{\infty} \tau \cdot \left(CF_k^l + TVL_{k-1} - TVL_k + TVL_{k-1} \cdot r_{k-1,k}\right) \cdot d_{t,k} = \tau \cdot (TVL_t - BEL_t)$$

As a result, the market value of liabilities can be represented as:

$$MVIL_t = BEL_t + RM_t^c + \tau \cdot (TVL_t - BEL_t) + \sum_{k=t+1}^{\infty} \tau \cdot (TVL_{k-1} - TVIA_{k-1}) \cdot \left(0 - r_{k-1,k}\right) \cdot d_{t,k}$$

This can in turn be rearranged and simplified as follows:

$$MVIL_t = BEL_t + RM_t + \tau \cdot \left(TVL_t - (BEL_t + RM_t)\right)$$

where the risk margin $RM_t = (RM_t^{rc} + RM_t^{zc} + RM_t^{\tau})/(1-\tau)$ is the sum of a capital risk margin based on the after-tax weighted average cost-of-capital and a frictional tax margin covering tax on investment income on the tax value of assets backing capital in excess of the tax value of insurance liabilities, hence:

$$RM_t^{\tau} = \sum_{k=t+1}^{\infty} \tau \cdot (TVL_{k-1} - TVIA_{k-1}) \cdot \left(0 - r_{k-1,k}\right) \cdot d_{t,k}$$

It is important to note that the frictional tax margin is based on the tax value of capital in excess of the tax value of insurance liabilities, as opposed to economic capital requirements. This is necessary to ensure consistency with the standard accounting deferred tax calculation, but is frequently overlooked (see chapter 5).

The above equation assumes that the tax value of the assets backing insurance liabilities and capital is known or can be replicated. If this is not the case, then the tax value of the replicating portfolio is assumed to be equal to its market value, $TVIA_t = MVIA_t$, which generally implies that the liability replicating instruments are sold and repurchased at each valuation date. Furthermore, if capital requirements are specified relative to the market value of insurance liabilities, then the market value of the assets must first be derived as follows:

$$MVIA_t = \sum_{k=t+1}^{\infty} \left(CF_{t,k}^{\text{pre-investment tax}} + \tau \cdot MVIA_{k-1} \cdot r_{k-1,k}\right) \cdot d_{t,k} = \sum_{k=t+1}^{\infty} CF_{t,k}^{\text{pre-investment tax}} \cdot d_{t,k}^{\text{after-tax}}$$

where:

i. $CF_{t,k}^{\text{pre-investment tax}} = -CF_k^l + MVIC_{k-1} \cdot \left(r_{k-1,k}^{rc} + 1\right) - MVIC_k + \tau \cdot \left(CF_k^l + TVL_{k-1} - TVL_k\right)$.

ii. $d_{t,k}^{\text{after-tax}} = \prod_{n=t+1 \text{ to } k} \left(r_{n-1,n}^{\text{after-tax}} + 1\right)^{-1}$ and $r_{t-1,t}^{\text{after-tax}} = (1-\tau) \cdot r_{t-1,t}$ are after-tax risk-free discount factors and interest rates.

3.4 Allowing for financial market risk, credit risk, and illiquidity

In chapter 2, the liability cashflows are assumed to be not subject to financial market risk and are default-free. As a result, they could be valued, using a replicating approach, by a portfolio of risk-free instruments. However, if the liability cashflows themselves are subject to financial market risk (such as in the case of participating life insurance contracts), then the liability replicating instruments are no longer risk-free. Assuming instead that the liabilities can be valued using instruments with a generic forward rate denoted $r_{t-1,t}^{\lambda}$, then the economic value of the liability cashflows is given by:

$$BEL_t^{\lambda} = \sum_{k=t+1}^{\infty} -CF_k^l \cdot d_{t,k}^{\lambda}$$

This approach can be extended to also cover credit risk and illiquidity premiums by assuming that these factors can also be valued using market instruments with the same features, such as credit default swaps or less liquid investments. Hence, it is assumed that the liability funding rate $r_{t-1,t}^{\lambda}$ incorporates spreads for financial market risk, credit risk, and illiquidity depending on the characteristics of the liability cashflows.

In section 2.1, economic earnings were based on a risk-free return on the market value of the insurance assets, given by $MVIA_{t-1} \cdot r_{t-1,t}$. As the assets backing the insurance liabilities are now assumed to earn a return of $r_{t-1,t}^{\lambda}$, this term is replaced by $BEL_{t-1}^{\lambda} \cdot r_{t-1,t}^{\lambda} + \left(MVIA_{t-1} - BEL_{t-1}^{\lambda}\right) \cdot r_{t-1,t}$, and the pre-tax insurance economic earnings are given by:

$$EE_t = CF_t^l + MVIL_{t-1} - MVIL_t + BEL_{t-1}^{\lambda} \cdot r_{t-1,t}^{\lambda} + \left(MVIA_{t-1} - BEL_{t-1}^{\lambda}\right) \cdot r_{t-1,t}$$

Equating this formula with the equity cost-of-capital, denoted $MVIE_{t-1} \cdot r_{t-1,t}^{\varepsilon} = EE_t$, and rearranging this equation, as in section 2.1, results in:

$$MVIL_{t-1} \cdot \left(1 + r_{t-1,t}\right) - MVIL_t = -CF_t^l - BEL_{t-1}^{\lambda} \cdot \left(r_{t-1,t}^{\lambda} - r_{t-1,t}\right) + MVIE_{t-1} \cdot \left(r_{t-1,t}^{\varepsilon} - r_{t-1,t}\right)$$

Solving this equation recursively, the market value of insurance liabilities is given by:

$$MVIL_t = BEL_t^{\lambda} + RM_t^c = BEL_t + RM_t^c + RM_t^{\lambda}$$

where $RM_t^{\lambda} = \sum_{k=t+1}^{\infty} -BEL_{k-1}^{\lambda} \cdot \left(r_{k-1,k}^{\lambda} - r_{k-1,k}\right) \cdot d_{t,k} = \sum_{k=t+1}^{\infty} CF_k^l \cdot \left(d_{t,k} - d_{t,k}^{\lambda}\right)$ is the liability margin, which is equal to the difference between the economic and risk-free discounted value of the liability cashflows.

Note that financial market risk relating to insurance liabilities is allowed for in the liability margin rather than the risk capital margin. In addition, the liability and risk capital margins do not cover financial market risk on investments not supporting insurance activities. As a result, the generic framework requires total risk capital to be decomposed into the part supporting insurance activities, $MVRC_t$, and the part that does not.

3.5 The generic economic valuation framework

Putting all the above components together, the market value of insurance liabilities is comprised of the risk-free discounted value of the best-estimate liability cashflows, a risk margin, and a deferred tax liability:

$$MVIL_t = BEL_t + RM_t + DTL_t$$

where:

i. $BEL_t = \sum_{k=t+1}^{\infty} -CF_k^l \cdot d_{t,k}$ is minus the best-estimate value of the liability cashflows at time *t*.

ii. $RM_t = RM_t^c + RM_t^\lambda$, covering pre-tax costs associated with funding the capital requirements as well as illiquidity premiums, and market and credit risk charges associated with funding the liability cashflows, where each component is based on the generic formula (see appendix):

$$RM_t^g = \sum_{k=t+1}^{\infty} CF_{t,k}^g \cdot \left(d_{t,k} - d_{t,k}^g\right) = \sum_{k=t+1}^{\infty} MV_{k-1}^g \cdot \left(r_{k-1,k}^g - r_{k-1,k}\right) \cdot d_{t,k}$$

iii. $DTL_t = \tau \cdot \left(TVL_t - (BEL_t + RM_t)\right)$ is a standard accounting deferred tax liability equal to the tax rate τ multiplied by the difference between the tax value and pre-tax market value of the liability.

3.5.1 Capital margin

The capital margin, given by $RM_t^c = (RM_t^{rc} + RM_t^{zc} + RM_t^\tau)/(1-\tau)$, incorporates the after-tax charge for funding the capital requirements and a frictional tax margin covering tax on investment income on the tax value of assets backing capital in excess of the tax value of the insurance liabilities. The after-tax capital margin is made-up of two components, an amount of allocated risk capital and a residual component covering any remaining capital requirements. The risk capital margin is usually covered by equity and qualifying hybrid debt and the residual capital margin may be covered by collateral facilities or senior debt.

a. For the risk capital margin RM_t^{rc}:

   i. $MV_t^{rc} = MVRC_t$ is the risk capital required to support the insurance liabilities at time *t*.

   ii. $r_{t-1,t}^{rc}$ is the weighted average after-tax cost-of-capital depending on the mix of senior debt, hybrid debt, and equity assumed to back the corresponding risk capital requirements, where the cost of equity capital associated with insurance risk is derived from the overall equity cost-of-capital by adjusting for new business profit and earnings not related to insurance activities (denoted $r_{t-1,t}^c$, see chapter 4).

b. For the residual capital margin RM_t^{zc}:

i. $CF_t^{zc} = BE_{t-1}^{zc} \cdot (1 + r_{t-1,t}) - BE_t^{zc}$ is the cash-flow at time t to maintain the residual capital requirements, where $BE_t^{zc} = MVIA_t - \left(BEL_t^{\lambda} + \tau \cdot \left(TVL_t - BEL_t^{\lambda}\right) + RM_t^{\tau} + RM_t^{rc} + MVRC_t\right)$ is the residual capital requirement plus the associated residual capital margin at time t.

ii. $r_{t-1,t}^{zc}$ is the weighted average after-tax cost-of-capital depending on the mix of debt, hybrid debt and equity assumed to back the residual capital requirements.

c. For the frictional tax margin RM_t^{τ}:

i. $MV_t^{\tau} = \tau \cdot (TVL_t - TVIA_t)$ is the tax value of excess allocated assets over the tax value of the liabilities required to support the insurance liabilities at time t multiplied by minus the tax rate. If the tax value of the assets is not known or cannot be replicated, then it is equal to the market value, $TVIA_t = MVIA_t$, and in the case that no residual capital is required the market value of the backing assets needs to be calculated as shown in section 3.3.

ii. $r_{t-1,t}^{\tau} = 0$ reflecting a forward interest rate of zero, as no interest is charged on deferred tax liabilities.

3.5.2 Liability margin

For the liability margin covering financial market and credit risk as well as illiquidity premiums RM_t^{λ}:

i. CF_t^{l} is the insurance liability cash-flow at time t.

ii. $d_{t,k}^{\lambda}$ is the discount factor, from time k to t, for liability funding covering financial market and credit risk as well as any illiquidity premium associated with the liability cashflows. These discount factors are not necessarily the same for all liability cashflows, they depend on the financial market and credit risk as well as illiquidity characteristics of the underlying liability cashflows.

Note that the liability margin is an asset if the underlying contract is a liability and a liability if the underlying contract is an asset.

The liability margin can be notionally split into margins for financial market risk, illiquidity, and credit (or own-credit) risk, as follows:

$$RM_t^{\lambda} = \sum_{k=t+1}^{\infty} -BEL_{k-1}^{\lambda} \cdot \left(r_{k-1,k}^{\lambda} - r_{k-1,k}\right) \cdot d_{t,k} = RM_t^{\text{illiquidity}} + RM_t^{\text{credit}} + RM_t^{\text{market}}$$

where:

i. $BEL_t^\lambda = \sum_{k=t+1}^{\infty} -CF_k^\lambda \cdot d_{t,k}^\lambda$ is minus the value of liability cashflows discounted at the liability funding rate.

ii. Each component is then derived by splitting the forward liability funding spread $r_{t-1,t}^\lambda - r_{t-1,t}$ into an illiquidity premium $s_{t-1,t}^{\text{illiquidity}}$, a charge for credit risk $s_{t-1,t}^{\text{credit}}$, or own-credit risk in the case that the underlying contract is a liability, and a charge for market risk $s_{t-1,t}^{\text{market}}$. As a result the forward funding spread is given by $r_{t-1,t}^\lambda - r_{t-1,t} = s_{t-1,t}^{\text{illiquidity}} + s_{t-1,t}^{\text{credit}} + s_{t-1,t}^{\text{market}}$, and the illiquidity margin, for example, is given by: $RM_t^{\text{illiquidity}} = \sum_{k=t+1}^{\infty} -BEL_{k-1}^\lambda \cdot s_{t-1,t}^{\text{illiquidity}} \cdot d_{t,k}$.

4 Calibrating insurance funding costs

By relaxing the last three simplifying assumptions detailed in section 2.1, this chapter shows how to calibrate the capital cost rates charged to insurance activities that should be used in the generic framework of section 3.5. In addition, it discusses approaches to calibrate the liability funding rate.

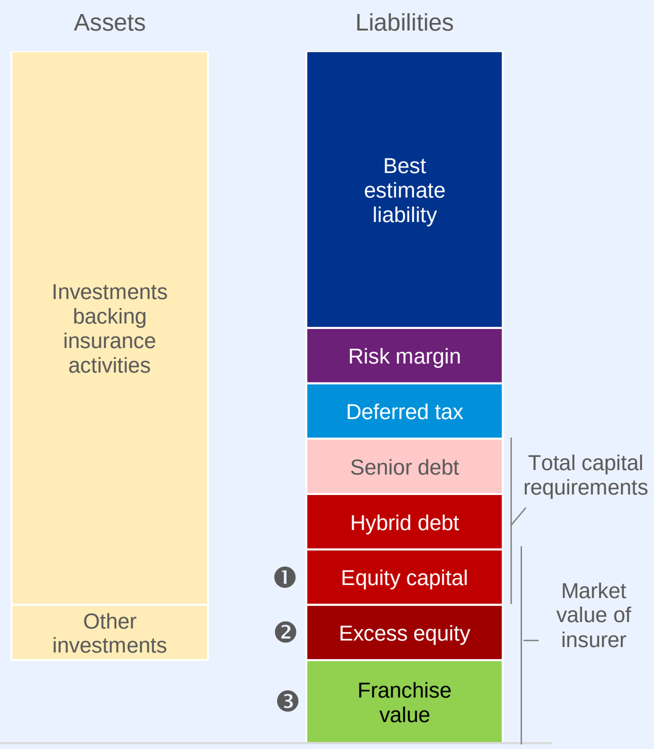
Insurer balance sheet

The market value of an insurer is comprised of:

❶ **Equity capital** allocated to support insurance activities. This is calculated as the difference between total capital requirements and (hybrid and senior) debt backing capital requirements.

❷ **Excess equity** equal to the difference between the available and required equity capital. Excess equity supports investment risk taking activities and the balance is generally available to support future dividends or potential new business opportunities.

❸ **Franchise value** equal to the difference between the market value of the insurer and available equity capital. Franchise value represents the present value of expected future economic profit on new business.



Note: for convience, it is assumed that all debt is allocated to insurance activities

4.1 Quantifying the insurance equity capital cost rate

The cost of equity capital associated with insurance activities can be derived from the insurer's overall equity cost-of-capital after allowing for the expected return on new business and non-insurance activities. Expected returns on non-insurance related activities are typically investment returns in excess of the funding costs associated with the liabilities and excess equity and debt.

As illustrated in chapter 2, the dividend discount model can be used to show that projected equity capital costs are equal to projected economic earnings. In chapter 2, it was assumed that the insurer held no excess capital or debt and was closed to new business. In this simplified case, equity capital costs equal capital requirements multiplied by the equity cost-of-capital rate.

Relaxing these simplifying assumptions means that the equity capital cost needs to be earned on the total market capitalisation of the firm, including equity supporting insurance capital requirements, excess equity capital, and franchise value, denoted $MVIE_{t-1} + MVXE_{t-1} + FV_{t-1}$. In addition, total projected economic earnings can be split into earnings attributable to in-force insurance activities, after-tax new business profit, and other non-insurance related earnings. As a result:

$$(MVIE_{t-1} + MVXE_{t-1} + FV_{t-1}) \cdot r^{\varepsilon}_{t-1,t} = EE_t = EEIA_t + NBP_t + EEO_t$$

It can also be shown that earnings attributable to in-force insurance activities are equal to the equity cost-of-capital related to insurance activities multiplied by the equity capital allocated to insurance activities, denoted $MVIE_t = MVIC_t - MVID_t - MVIH_t$. This is given by:

$$EEIA_t = MVIE_{t-1} \cdot r^{c}_{t-1,t}$$

Hence by combining and rearranging the above equations, the insurance equity capital cost forward rate can be shown to be equal to the overall cost of equity capital adjusted for after-tax new business profit, economic earnings attributable to non-insurance activities, and equity capital costs on excess equity and the franchise value. This is represented as follows:

$$r^{c}_{t-1,t} = r^{\varepsilon}_{t-1,t} - \left(NBP_t + EEO_t - (MVXE_{t-1} + FV_{t-1}) \cdot r^{\varepsilon}_{t-1,t}\right)/MVIE_{t-1}$$

As the franchise value reflects the present value of future new business profit, it can be represented as a perpetuity and $NBP_t = FV_{t-1} \cdot \left(r^{\varepsilon\,\text{new business}}_{t-1} - g^{\text{new business}}_{t-1}\right)$, where $r^{\varepsilon\,\text{new business}}_{t-1}$ is the new business cost of capital and $g^{\text{new business}}_{t-1}$ is the expected growth in new business profit. As a result:

$$r^{c}_{t-1,t} = r^{\varepsilon}_{t-1,t} - \frac{FV_{t-1} \cdot \left(r^{\varepsilon\,\text{new business}}_{t-1} - g^{\text{new business}}_{t-1} - r^{\varepsilon}_{t-1,t}\right)}{MVIE_{t-1}} - \frac{EEO_t - MVXE_{t-1} \cdot r^{\varepsilon}_{t-1,t}}{MVIE_{t-1}}$$

Therefore the cost of capital rate associated with insurance risk is equal to the overall equity cost-of-capital rate adjusting for:

i. new business, to the extent that expected new business profit is valued using a higher discount rate than the overall equity cost-of-capital, after allowing for new business growth.

ii. economic earnings from non-insurance related activities (see section 4.1.1 below) in excess of the equity capital costs attributable to these activities.

Note that above formula for the cost of capital rate associated with insurance risk needs to be calculated iteratively as the adjustments require an economic balance sheet, which in turn depends on the insurance cost of capital rate.

4.1.1 Other economic earnings

Other economic earnings is derived by subtracting economic earnings associated with insurance activities from total after-tax economic earnings. Total after tax economic earnings is comprised of pre-tax economic earnings on existing business, less tax including the unwind of deferred tax on the investments given by $\tau \cdot \left(TVA_{t-1} \cdot r_{t-1,t}^{\beta\, tax} - MVA_{t-1} \cdot r_{t-1,t}^{\beta}\right)$, less after-tax interest expense on debt funding, plus after-tax new business economic profit. As a result:

$$EE_t = \left(CF_t^l + MVIL_{t-1} - MVIL_t + MVA_{t-1} \cdot r_{t-1,t}^{\beta}\right) - \tau \cdot \left(CF_t^l + TVL_{t-1} - TVL_t + MVA_{t-1} \cdot r_{t-1,t}^{\beta}\right)$$
$$-(1-\tau) \cdot \left((MVIH_{t-1} + MVXH_{t-1}) \cdot r_{t-1,t}^{\gamma} + (MVID_{t-1} + MVXD_{t-1}) \cdot r_{t-1,t}^{\delta}\right) + NBP_t$$

where $MVA_t = MVIA_t - DTIA_t + \tau \cdot (MVA_t - TVA_t) + MVXE_t + MVXH_t + MVXD_t$ is the market value of total assets, which is comprised of the assets assigned to insurance activities plus deferred tax on the excess investments and excess capital.

Therefore, after subtracting the after-tax economic earnings from in-force insurance activities and after-tax new business profit, the other economic earnings are given by:

$$EEO_t = MVA_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\beta} - \left(MVIA_{t-1} - BEL_{t-1}^{\lambda}\right) \cdot (1-\tau) \cdot r_{t-1,t} - BEL_{t-1}^{\lambda} \cdot (1-\tau) \cdot r_{t-1,t}^{\lambda}$$
$$-MVXH_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\gamma} - MVXD_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\delta}$$

As a result, other economic earnings are essentially the after-tax investment income on the total assets less the investment income required to support the insurance liabilities, and the cost of funding the excess senior and hybrid debt requirements.

4.2 Quantifying the liability funding cost rate

The liability funding rate reflects compensation for financial market risk, credit risk, and illiquidity associated with the liability cashflows. These rates are typically not observable as insurance liabilities are not traded. Nevertheless the spread for market risk can be estimated by constructing a replicating portfolio of available financial market instruments that matches the liability cashflows as closely as possible.

The spreads for credit risk and illiquidity can be estimated from corporate bond spreads adjusting for the credit quality of the liability cashflows, to reflect credit risk exposure from the perspective of the holder of the insurance asset (typically the client). This should include allowing for industry and government protection schemes as well as the provision of collateral or other credit enhancement features in underlying contract wording. Splitting these spreads into an illiquidity premium and credit charge is technically possible using multivariate models of bond spreads or by deriving illiquidity premiums from differences in spreads on bonds with similar credit quality but different market liquidity (such as off and on the run government bonds).

5 Interpreting existing valuation frameworks

This chapter compares the generic framework for valuing insurance liabilities presented in chapter 3 with the requirements of other economic valuations, including the European Union Solvency II, the Swiss Solvency Test, CFO Forum © Market Consistent Embedded Value, and the new international accounting standard on insurance (IFRS 17). In so doing it provides the basis for interpreting cost-of-capital rates used, in particular the 6% spread specified under Solvency II and the Swiss Solvency Test.

5.1 EU Solvency II

EU Solvency II regulations specify that technical provisions should equal to the present value of best estimate insurance liability cashflows and a cost-of-capital risk margin based on a 6% capital cost rate applied to the solvency capital requirement, and that deferred tax on these technical provisions should be recognised in the standard manner based on the difference between the value of the liabilities for tax purposes and the technical provisions. In addition, in certain cases a liability margin may be taken into account via a so-called matching adjustment.

As a result the Solvency II value of the liabilities, including deferred tax, is defined as:

$$MVIL_t^{SII} = BEL_t + RM_t^{SCR} + RM_t^{\text{matching adj}} + \tau \cdot \left(TVL_t - \left(BEL_t + RM_t^{SCR} + RM_t^{\text{matching adj}}\right)\right)$$

where:

i. $RM_t^{SCR} = \sum_{k=t+1}^{\infty} SCR_{k-1} \cdot \epsilon^{SII} \cdot d_{t,k}$ is the capital cost risk margin at time *t*, where SCR_t is the solvency capital requirement, excluding avoidable financial market risk on the investments, and $\epsilon^{SII} = 6\%$ is the annual cost-of-capital spread.

ii. $RM_t^{\text{matching adj}} = \sum_{k=t+1}^{\infty} CF_k^l \cdot \left(d_{t,k} - d_{t,k}^{SII}\right)$ is the value of the matching adjustment at time *t*, where $d_{k,t}^{SII}$ is the liability discount factor including a matching adjustment equal to the spread on matching investments plus in the case of insurance assets a spread for credit risk.

Hence the Solvency II method is a special case of the generic framework with the restrictions:

i. It is assumed that no debt financing is used and there are no residual capital requirements.

ii. No allowance for own credit risk is permitted.

iii. The allowance for tax on investment income on capital is either implicitly reflected in the calibration of the capital cost rate or not allowed for.

iv. The capital cost rate is only charged on the solvency capital requirement, whereas in practice most insurer's aim to hold a multiple of the solvency capital requirement.

Comparing the capital cost risk margins in more detail reveals that:

$$\epsilon^{SII} = \left(\left(\frac{r_{k-1,k}^c}{1-\tau} - r_{k-1,k}\right) + \frac{(MVIL_{k-1} - TVL_{k-1}) \cdot \tau \cdot r_{k-1,k}}{MVIE_{k-1} \cdot (1-\tau)}\right) \cdot \left(\frac{MVIE_{k-1}}{SCR_{k-1}}\right)$$

This suggests that there is scope for reconsidering the 6% rate used in Solvency II on the grounds that certain key aspects were not allowed for when this rate was derived[3]. In deriving the 6% rate it was assumed that the equity cost-of-capital spread for insurance companies was in the range of 7.5-10%, derived from CAPM or Fama-French multi-factor models. Consideration was given to hybrid debt, which was assumed to be insignificant, and to return on franchise value but no attempt was made to quantify this impact. However the following key aspects were not taken into account:

[3] See CEIOPS-DOC-36/09.

i. Taxation. In particular, the cost of equity estimate of 7.5-10%, represents an after-tax spread, whereas the Solvency II method is implicitly based on a pre-tax spread. This suggests that the cost-of-capital spread should be grossed-up for tax.

ii. Excess return on investments. It is implicitly assumed that the cost of equity attributable to insurance risk is proportionate to the allocation of the overall capital requirements to insurance risk. However this is unlikely to be the case due to the different nature of insurance and financial market risk and the extent to which these risks diversify within an insurer compared to with the overall market. This is important as financial market risk is a key driver of the overall cost of equity for most insurers, given the extent to which they are leveraged and the amount of financial market risk typically taken. The cost-of-capital rate associated with insurance activities should rather be estimated using the approach described in section 4.1.

iii. Matching adjustment, which should be added back to the capital cost rate.

5.2 Swiss Solvency Test

The Swiss Solvency Test (SST) is pre-tax and defines the pre-tax value the liabilities as:

$$MVIL_t^{\text{pre-tax}\,SST} = BEL_t + RM_t^{SST}$$

where: $RM_t^{SST} = \sum_{k=t+1}^{\infty} RC_{k-1}^{SST} \cdot \epsilon^{SST} \cdot d_{t,k-1}$ is the market value margin at time t, where RC_k^{SST} is the solvency capital requirement for insurance risk at time k, and $\epsilon^{SST} = 6\%$ is the insurance cost-of-capital spread.

This shows that the SST method is also a special case of the generic framework and is similar to the Solvency II approach. Hence compared to the generic framework it does not allow for debt financing and own credit risk, the cost-of-capital spread reflects a pre-tax rate taking into account tax on investment income on capital, and the capital cost rate is charged only on the solvency capital requirement. The main differences compared to the Solvency II approach are:

i. SST capital adequacy is determined on a pre-tax basis. Thus the balance sheet is pre-tax and does not correspond to the market value of equity.

ii. Solvency capital requirements are determined on different bases, in particular SST is based on 99% TailVaR as opposed to 99.5% VaR for Solvency II.

iii. The only liability funding costs allowed for in SST are financial market risk and credit risk on insurance assets. SST does not allow for use of a liquidity premium nor own credit risk.

iv. The SST risk margin is based on risk-free discount factors at the start of each interval rather than the end. This means that the SST capital cost spread is defined based on the following formula: $\epsilon^{SST} = \left((r_{k-1,k}^{SST} + 1)/(r_{k-1,k} + 1) - 1\right)$, compared to the Solvency II capital cost spread definition: $\epsilon^{SII} = \left(r_{k-1,k}^{SII} - r_{k-1,k}\right)$. The SST specification of the capital cost spread is preferable for determining the interest sensitivity of the tax and capital cost components of the market value of insurance liabilities.

In aggregate, these differences mean that the SST rate of 6% is more conservative than the equivalent Solvency II rate.

5.3 Market Consistent Embedded Value

The European Insurance CFO Forum Market Consistent Embedded Value (MCEV)[4] is conceptually the same as the market value of shareholder equity defined in this paper. This is defined as:

$$MCEV_t = ANAV_t + CEPVFP_t + TVOG_t + CRNHR_t + FC_t$$

where:

i. $ANAV_t$ is shareholder equity calculated based on statutory accounting principles.

ii. $CEPVFP_t$ is the certainty equivalent (essentially risk-free) present value of future after-tax profits.

iii. $TVOG_t$ is the time value of options and guarantees, which together with the $CEPVFP_t$ gives the present value of future best-estimate after-tax profits.

iv. $CRNHR_t$ is the cost of residual non-hedgeable risks, which is essentially a risk margin allowing for insurance and other risks that cannot be hedged using traded market instruments.

v. $FC_t = FCT_t + FCE_t$ is the sum of tax and investment expenses associated with future investment income on shareholder equity.

This is an indirect approach to defining the equity of the insurer. However, since the statutory value of the liabilities plus the certainty equivalent value of future profits and the time value of options and guarantees is equal to the best-estimate liabilities and since future tax payments are taken into account, as a result:

$$MVIL_t^{MCEV} = BEL_t + FCE_t + RM_t^{MCEV} + \tau \cdot \left(TVL_t - (BEL_t + RM_t^{MCEV})\right)$$

where: RM_t^{MCEV} is a pre-tax capital cost risk margin based on an after-tax spread of ϵ^{MCEV}, given by:

$$RM_t^{MCEV} = \frac{CRNHR_t + FCT_t}{1-\tau} = \sum_{k=t+1}^{\infty} MVIC_{k-1} \cdot \left(\frac{\epsilon^{MCEV} + r_{k-1,k}}{1-\tau} - r_{k-1,k} \right) \cdot d_{t,k}$$

This shows that the MCEV method is also consistent with the generic framework. The main differences are:

i. Own credit risk is not taken into account, which is inconsistent with the MCEV principles of using market consistent values of all assets and liabilities. In particular, it is inconsistent with valuing debt at market value.

ii. The allowance for tax on investment income on capital is inconsistent with the calculation of after-tax profits on future earnings based on the run-off of the tax value of the liabilities (see section 3.3).

iii. The capital cost rate is based on internal estimates that are not necessarily consistent with the calibration presented in section 4.1.

iv. The best estimate value of the liabilities includes future investment expenses related to assets backing insurance capital requirements.

5.4 IFRS 17

The International Financial Reporting Standard for insurance activities, IFRS 17, allows insurers to use a cost-of-capital approach to determine the risk adjustment for non-financial risk. To date little guidance has been given on how this risk adjustment should be specified.

While it is not permitted to allow for own-credit risk, an allowance for illiquidity premiums is permitted. Not allowing for own-credit risk is inconsistent with the international financial reporting standards for the valuation of debt and derivatives, as well as with allowing for counterparty credit risk in the valuation of insurance assets. This could also distort the classification of onerous contracts and understate risk margins on insurance contracts that significantly contribute to the insurer's default risk.

This paper provides a basis that can be used to assess the risk adjustments applied by insurers, in particular to ensure that the insurance cost-of-capital is consistent with the firm's equity cost-of-capital and with the deferred tax calculation.

6 Appendix: notation

6.1 Key parameters

The table below lists the main parameters used in the paper (interest rates are described below).

Variable	Description
$MVIL_t$	Market value of insurance liabilities (including deferred tax on liabilities)
TVL_t	Tax value of insurance liabilities
$MVIC_t$	Market value of total capital requirements associated with insurance activities
$MVRC_t$	Risk capital requirements associated with insurance activities
$MVZC_t$	Residual capital requirements associated with insurance activities
$MVIA_t$	Market value of assets backing insurance activities
$TVIA_t$	Tax value of assets backing insurance activities
CF_k^l	Insurance liability cashflows, including premiums less claims and expenses
DIV_t	Dividends paid
EE_t	Insurer's total after-tax economic earnings
$EEIA_t$	After-tax economic earnings associated with the in-force insurance activities
EEO_t	Other, non-insurance related, after-tax economic earnings
$MVIE_t$	Market value of shareholder's equity allocated to insurance activities
$MVXE_t$	Market value of shareholder's equity allocated to non-insurance activities
$MVIH_t$	Market value of qualifying hybrid debt allocated to insurance activities
$MVXH_t$	Market value of excess hybrid debt allocated to non-insurance activities
$MVID_t$	Market value of senior debt allocated to insurance activities
$MVXD_t$	Market value of excess senior debt allocated to non-insurance activities
MVA_t	Market value of insurer's total investments
TVA_t	Tax value of insurer's total investments
NBP_t	After-tax new business profits
FV_t	Franchise value of the insurer or present value of new business profits
τ	Corporate tax rate on taxable income

6.2 Discount factors and forward rates

Discount factors from time k to time t are denoted $d_{t,k}^x$, based on spot rate spreads denoted x_t over risk-free spot rates denoted r_t. Where no spread is shown, the discount factors are risk-free discount factors. Hence:

$$d_{t,k}^x = \frac{(1 + r_k + x_k)^{-k}}{(1 + r_t + x_t)^{-t}}$$

In addition, the corresponding forward rate from time t to time k is denoted $r_{t,k}^x$, where:

$$r_{t.k}^{x} = \frac{(1 + r_k + x_k)^k}{(1 + r_t + x_t)^t} - 1 = d_{k,t}^{x} - 1$$

The table below defines the discount factors and corresponding forward rates used in the paper:

Discount factor	Forward rate	Description
$d_{t,k}$	$r_{t-1,t}$	Risk-free rate
$d_{t,k}^{\text{tax}}$	$r_{t-1,t}^{\text{tax}}$	Taxable return on risk-free instruments
$d_{t,k}^{\text{after-tax}}$	$r_{t-1,t}^{\text{after-tax}}$	After tax risk-free rates, where $r_{t-1,t}^{\text{after-tax}} = (1-\tau) \cdot r_{t-1,t}$
$d_{t,k}^{\varepsilon}$	$r_{t-1,t}^{\varepsilon}$	Insurer's cost-of-equity
$d_{t,k}^{\gamma}$	$r_{t-1,t}^{\gamma}$	Insurer's qualifying hybrid, or subordinate, debt funding rate
$d_{t,k}^{\delta}$	$r_{t-1,t}^{\delta}$	Insurer's senior debt funding rate
$d_{t,k}^{c}$	$r_{t-1,t}^{c}$	Cost of equity capital associated with insurance activities
$d_{t,k}^{rc}$	$r_{t-1,t}^{rc}$	Weighted average after-tax cost-of-capital on risk capital
$d_{t,k}^{zc}$	$r_{t-1,t}^{zc}$	Weighted average after-tax cost-of-capital on residual capital
$d_{t,k}^{\lambda}$	$r_{t-1,t}^{\lambda}$	Insurance liability rate (including spreads for $s_{t-1,t}^{\text{illiquidity}}$, $s_{t-1,t}^{\text{credit}}$, $s_{t-1,t}^{\text{market}}$)
$d_{t,k}^{\beta}$	$r_{t-1,t}^{\beta}$	Market return on insurer's investment portfolio
$d_{t,k}^{\beta\ \text{tax}}$	$r_{t-1,t}^{\beta\ \text{tax}}$	Return on insurer's investment portfolio subject to tax

In addition, $r_{t-1}^{\varepsilon\ \text{new business}}$ is the new business cost of capital and $g_{t-1}^{\text{new business}}$ is the expected growth in new business profit, such that:

$$FV_{t-1} = \frac{NBP_t}{r_{t-1}^{\varepsilon\ \text{new business}} - g_{t-1}^{\text{new business}}}$$

The weighted average after-tax cost-of-capital for the risk and residual margins are given by:

$$r_{t-1,t}^{rc} = \frac{\rho^{rc,E} \cdot MVIE_{t-1} \cdot r_{t-1,t}^{c} + \rho^{rc,H} \cdot MVIH_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\gamma} + \rho^{rc,D} \cdot MVID_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\delta}}{MVRC_{t-1}}$$

$$r_{t-1,t}^{zc} = \frac{\rho^{zc,E} \cdot MVIE_{t-1} \cdot r_{t-1,t}^{c} + \rho^{zc,H} \cdot MVIH_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\gamma} + \rho^{zc,D} \cdot MVID_{t-1} \cdot (1-\tau) \cdot r_{t-1,t}^{\delta}}{MVZC_{t-1}}$$

where:

i. $MVRC_t = \rho^{rc,E} \cdot MVIE_{t-1} + \rho^{rc,H} \cdot MVIH_{t-1} + \rho^{rc,D} \cdot MVID_{t-1}$ is the amount of risk capital and $\rho^{rc,E}$, $\rho^{rc,H}$, and $\rho^{rc,D}$ are the allocations to risk capital of equity, hybrid, and senior debt backing insurance activities. Typically $\rho^{rc,E} = \rho^{rc,H} = 1$ and $\rho^{rc,D} = 0$, as risk capital needs to be loss absorbing, whereas residual capital requirements can be funded at lower cost using senior debt.

ii. $MVZC_t = \rho^{zc,E} \cdot MVIE_{t-1} + \rho^{zc,H} \cdot MVIH_{t-1} + \rho^{zc,D} \cdot MVID_{t-1}$ is the amount of residual capital and $\rho^{zc,E} = 1 - \rho^{rc,E}$, $\rho^{zc,H} = 1 - \rho^{rc,H}$, and $\rho^{zc,D} = 1 - \rho^{rc,D}$ are the allocations to residual capital of equity, hybrid, and senior debt backing insurance activities.

iii. $MVIE_t = MVIC_t - MVID_t - MVIH_t$ is the total equity backing insurance activities, where the total capital requirement is the sum of allocated risk capital plus and residual funding requirements, denoted $MVIC_t = MVRC_t + MVZC_t$. Apart from the special case where $\rho^{rc,E} = \rho^{rc,H} = 1$ and $\rho^{rc,D} = 0$, the residual funding requirement, $MVZC_t$, is unknown and needs to be calculated iteratively.

iv. $MVIH_t$, and $MVID_{t-1}$ are performance allocations of the total hybrid, and senior debt to insurance activities.

6.3 Risk margins

Risk margins can be expressed in various ways. Firstly in the standard Solvency II manner of the present value of a funding requirement multiplied by a funding spread. Secondly, as the risk-free discounted value of the future cashflows associated with the funding less the current market value of the funding requirement. This can be expressed generically as:

$$RM_t^g = \sum_{k=t+1}^{\infty} MV_{k-1}^g \cdot \left(r_{k-1,k}^g - r_{k-1,k}\right) \cdot d_{t,k} = \sum_{k=t+1}^{\infty} MV_{k-1}^g \cdot \left(\frac{d_{k-1,k}}{d_{k-1,k}^g} - 1\right) \cdot d_{t,k-1} = \sum_{k=t+1}^{\infty} CF_k^g \cdot \left(d_{t,k} - d_{t,k}^g\right)$$

where:

i. $MV_t^g = \sum_{k=t+1}^{\infty} CF_k^g \cdot d_{t,k}^g$ is the market value of the generic funding cashflows at time *t*.

ii. $BE_t^g = \sum_{k=t+1}^{\infty} CF_k^g \cdot d_{t,k}$ is the risk-free discounted value of the generic funding cashflows.

iii. $CF_t^b = MV_{t-1}^g \cdot \left(1 + r_{t-1,t}^g\right) - MV_t^g = BE_{t-1}^g \cdot \left(1 + r_{t-1,t}\right) - BE_t^g$ is the funding cash-flow at time t.

This means the time intervals used to calculate funding costs should correspond to the frequency with which funding is repaid or redeployed.